



EVALUATION OF THE PRODUCTIVE ZONE OF THE FAHILIAN RESERVOIR USING REAL-TIME GAS ANALYSIS IN DRILLING MUD AT THE YADAVARAN FIELD, ABADAN PLAIN

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ABSTRACT

During the drilling of hydrocarbon reservoirs, valuable data is collected that can be used for the characterization of hydrocarbon reservoirs, particularly the production zones. One such dataset is the gas content in the drilling mud, specifically the analysis of the gas released from the mud. This study aims to investigate the productive zone by using real-time gas analysis of the gas present in the drilling mud from a field located in southwestern Iran. The focus of the study is on two wells in the Yadavaran field, located in the Khuzestan province within the Abadan Plain. The gas data from these two wells were individually analyzed, considering both their geological context and gas composition. The findings revealed that the Fahilian formation in the Yadavaran field has reservoir potential, with clear evidence of hydrocarbons observable through gas composition and petrophysical logs. Additionally, due to lithological variations in the Fahilian formation between these two geographically aligned wells, the concentration of light gas components was higher in well No. 19 compared to well No. 9. This difference may suggest a lack of continuity in the reservoir in this particular section.

Keywords: Gas in drilling mud, Fahilian formation, productive zone, reservoir continuity.

INTRODUCTION

During the drilling of hydrocarbon reservoirs, valuable data is collected that can be used to characterize the production layers of the reservoirs. One such dataset is the gas content in the drilling mud, which involves real-time analysis of the gas released from the mud. Throughout the drilling process, the gas sampling system operates continuously, with the interpretation of the analysis data occurring in real time. By identifying trends in gas composition and changes in their ratios, it becomes possible to examine variations in lithology and fluid content of the drilled formations. This information can then be used to guide the well drilling process (3). The

use of gas analysis during drilling is crucial due to its agile data collection and ability to prevent potential hazards, such as blowouts, thus ensuring the safety and efficiency of the drilling process. Additionally, the interpretive data from this method can be valuable for optimizing well-testing operations (4). The measurement of hydrocarbon gases in drilling mud is conducted using gas chromatography, which includes quality control of sampling at specific intervals and the analysis of gas samples through hydrocarbon gas ratios (2). The accurate recording of these gases, along with their proper geochemical analysis, plays a crucial role in real-time reservoir evaluation and description. This is because the gas data obtained during well drilling reveals distinctive gas indicators across various formations (5). The more accurately hydrocarbon gases are identified, and the broader the spectrum of hydrocarbons considered, the better the assessment of the formation during drilling. This improves the determination of fluid levels in the reservoir and the identification of productive zones with higher precision and clarity (6).

The objective of this study is to analyze and determine the productive zones and continuity of the Fahilian reservoir in the Yadavaran field, located in the Abadan Plain, through the geochemical evaluation of hydrocarbon gases present in the drilling mud.

GEOLOGY OF THE STUDY AREA

The Zagros sedimentary basin, which spans over 1,800 kilometers, is located along the northeastern edge of the Arabian Plate. The Abadan Plain is a significant sub-basin of this sedimentary basin, particularly in terms of hydrocarbon resources, and is bordered by the Dezful Depression, the Persian Gulf, and Iraq. Its northern-northeastern boundary is marked by the Zagros fold-thrust front, which includes the southern edges of the Sussangerd, Ab Timor, and Mansouri anticlines. The basin extends south of the Rag Sefid field and reaches into the Persian Gulf (7). This region is home to more than seven major oil fields, such as the Darquain, Jaffir, Yadman, Yaran, Yadavaran, and Azadegan fields (Figure 1), with oil production primarily derived from Cretaceous-aged reservoirs (Kobraie). The Abadan Plain is part of the Mesopotamian sedimentary basin, which is characterized by low seismicity and distinct structural features compared to the Dezful Depression (Zeinalzadeh, *Journal of Natural Gas Science and Engineering*, 26, 2015, 419–426). The anticlines in this basin trend north-south, in contrast to the general northwest-southeast trend of structures in the Zagros sedimentary basin (Saadatinejad and Sarkarinejad, 2011). These north-south structures are believed to have originated during the Natibah orogeny in the late Proterozoic (Satarzadeh, Cosgrove, and Vita-Finzi, 1999). Furthermore, the dip of these structures is mild, in contrast to the steeper dip observed in the Dezful Depression. The surface of the plain is covered by modern alluvial deposits, and the structures do not exhibit any outcrops. While the Asmari formation is the primary reservoir in the Dezful Depression, the Bangestan and Khami formations are the key contributors to oil and gas accumulation in the Abadan Plain (Aghanabati, 1383).

The Yadavaran field is located in the Abadan Plain, north of Khorramshahr (Figure 1), covering an area of 15×45 kilometers. This field is a combination of the Hosseiniyeh and Koushk anticlines and does not have surface outcrops, being discovered through geophysical surveys. The trend of its anticline follows the north-south direction of the Darquain, Khorramshahr, and Azadegan structures. The Yadavaran field is adjacent to the Sinbad field in Iraq. Both heavy and light crude oils are extracted from the Sarvak and Fahilian formations, respectively, with an estimated in-place oil reserve of 17 billion barrels (Aghanabati, 1383).

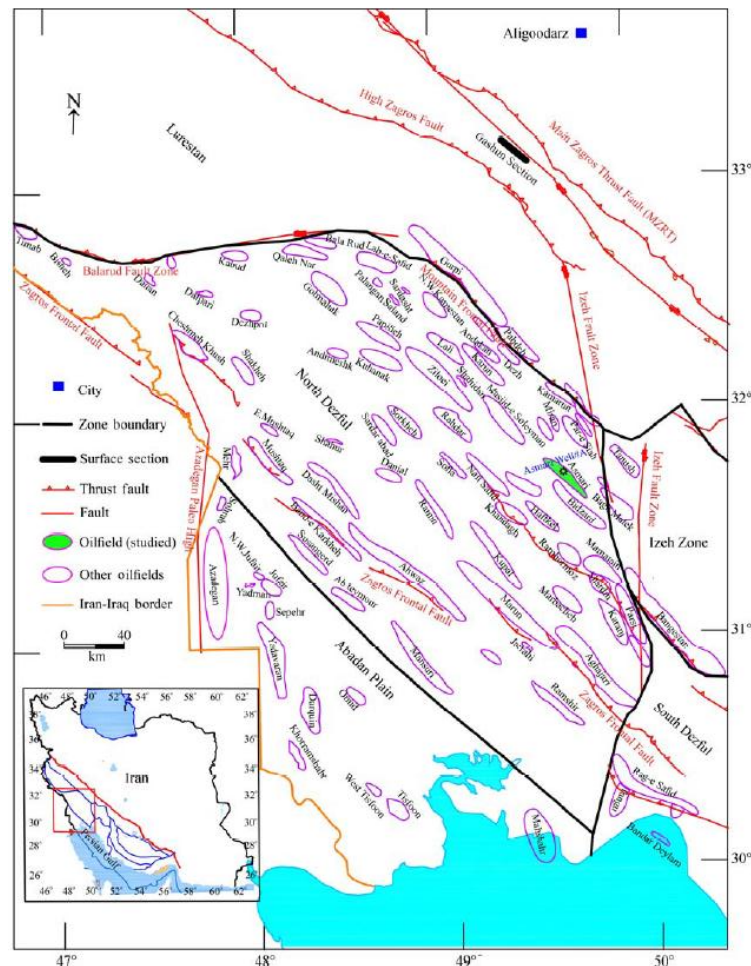


Figure 1: Map of the location of fields in the Abadan Plain within the Zagros sedimentary basin (modified from Sadouni and Rabbani, 2018).

In this study, data from two wells drilled into the Fahilian reservoir were utilized for drilling mud gas analysis. The Fahilian formation consists of limestone and is gray in color. Samples from this formation, when combined with oil, fluoresce in bright yellow under UV light with high luminosity.

METHODOLOGY

The gas data recording and storage from the drilling mud in two wells of the Yadavaran field were conducted using a gas chromatograph with a flame ionization detector. The gases associated with the drilling mud are separated from the mud by gas trap motors and subsequently directed into the gas chromatograph. The data is recorded based on the gas volume and the time it enters the detector. It is important to note that the device is calibrated daily using standard samples. Once the gas enters and is analyzed by the device, the quality of the recorded data is reviewed. For this purpose, the Gas Quality Ratio (GQR) index is used. This index is derived from the ratio of the total gas volume to the sum of the hydrocarbon component volumes, multiplied by the number of carbon atoms in each component (Newto, 2014; Wiersberg, 2007). A GQR value in the range of 0.8 to 1.2 indicates good data quality. The results of the recorded gas data from the two wells under study show that the data quality is satisfactory.

DISCUSSION

1. Well No. 9

Based on the drilling mud gas survey data, which is also displayed on the right side of the geological log, the logs for each hydrocarbon component were plotted and are presented below.

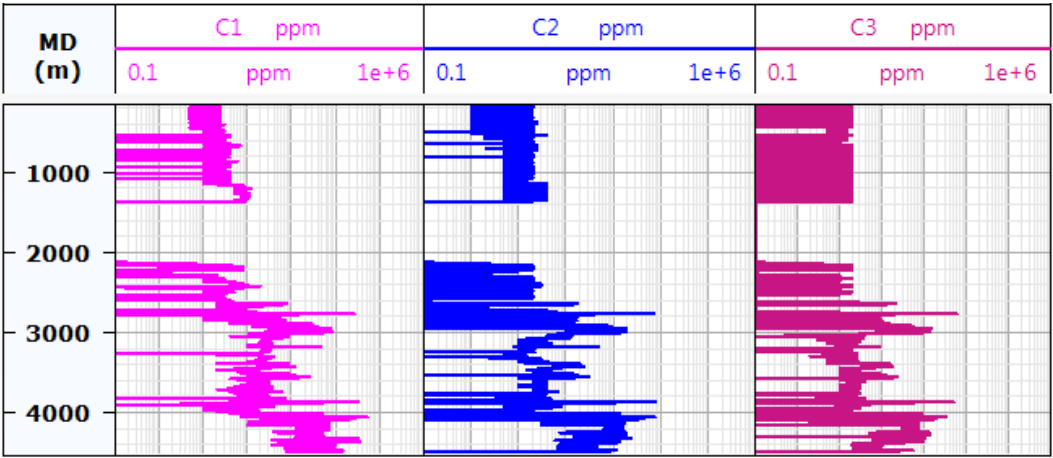


Figure 5: Interpretation of the distribution of C1 to C3 gas components in the drilling mud in Well No. 9.

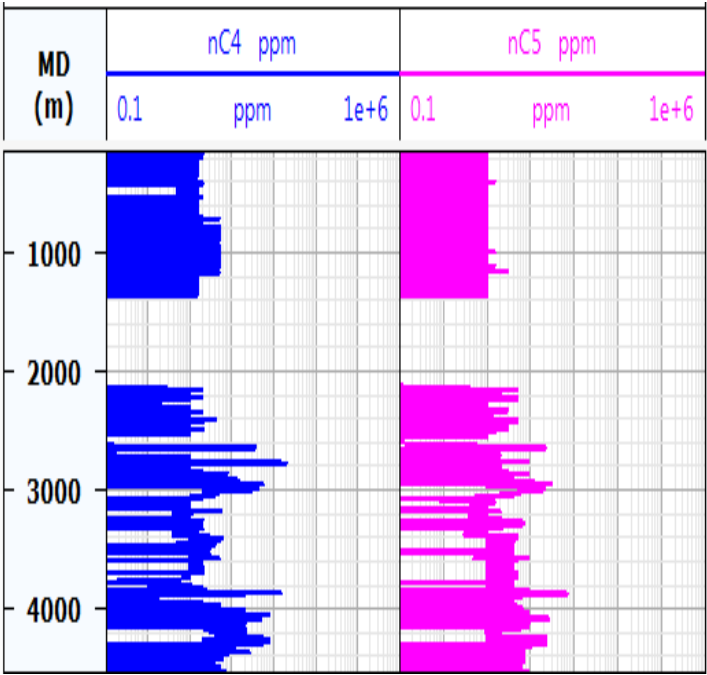


Figure 6: Interpretation of the distribution of C4 to C5 gas components in the drilling mud in Well No. 9.

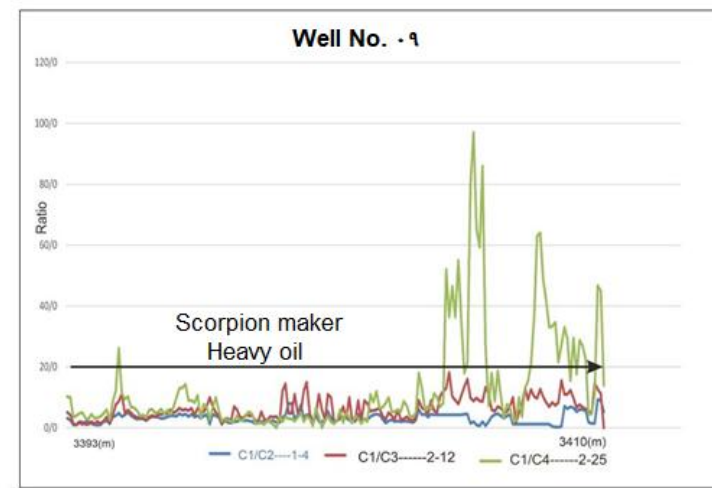


Figure 7: Advanced gas mud data interpretation for the Koojdami Formation, Well No. 9 (Pixelar chart).

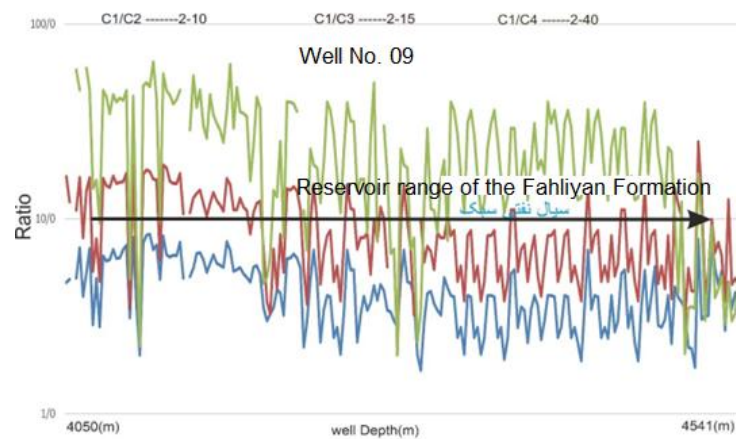


Figure 8: Advanced gas mud data interpretation for the Fahliyan Formation, Well No. 9 (Pixelar chart).

2. Well No. 19

Based on the drilling mud gas survey data, which was also shown on the right side of the geological log, the logs of each hydrocarbon component were plotted and are presented below.

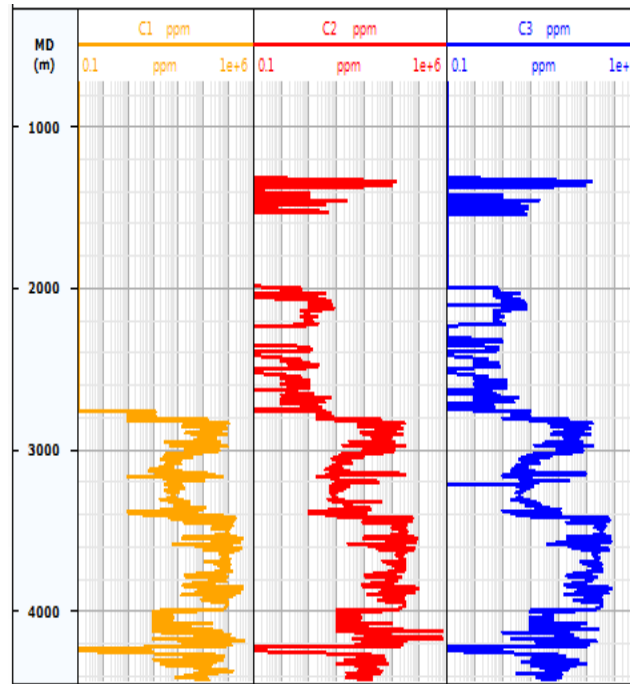


Figure 9: Interpretation of the Distribution Data of C1 to C3 Mud Gas Components in Well 19

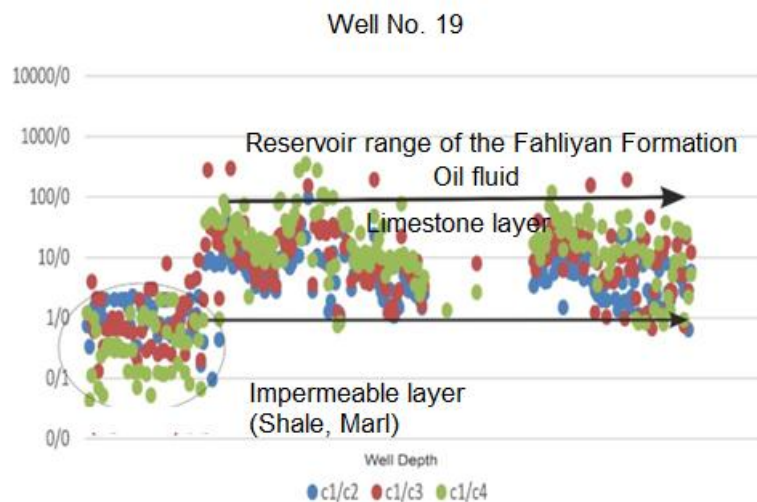


Figure 10: Interpretation of Advanced Mud Gas Data for the Fahliyan Formation in Well 19 (Pixler Diagram)

Overall, it appears that, based on the C1/C2 index in Figure 10 and the gas ratio Pixler diagram, this well contains liquid oil in two reservoir horizons. The parameters on the Pixler diagram fall within the liquid phase region, which is also highlighted separately in the figure. According to the gas-to-liquid ratio (G/L), the well fluid under study is within a range below 100, indicating an oil-type fluid. Initially, upon entering the Fahliyan Formation, the gas values are low due to the presence of shale and marl layers, which have poor permeability. However, after passing through these layers and entering the limestone layer, along with changes in porosity and permeability, these ratios begin to increase.

The Fahliyan Formation in the Yadavaran field demonstrates reservoir potential, with clear hydrocarbon evidence observable from gas compositions and petrophysical logs. This study analyzed the gas compositions of two wells in the Yadavaran field. Based on gas ratios, wettability, hydrocarbon balance, and the hydrocarbon index, as well as the discrepancy between the wettability ratio and the hydrocarbon balance, the fluid type was identified as oil,

specifically light oil. This conclusion is further supported by the specific gravity of the oil in the Fahliyan Formation. Additionally, considering the lithological variations between these two wells—both located in the same geographical direction—the amount of light gas components in Well No. 19 was higher than in Well No. 9. This may indicate a lack of reservoir continuity in this area.

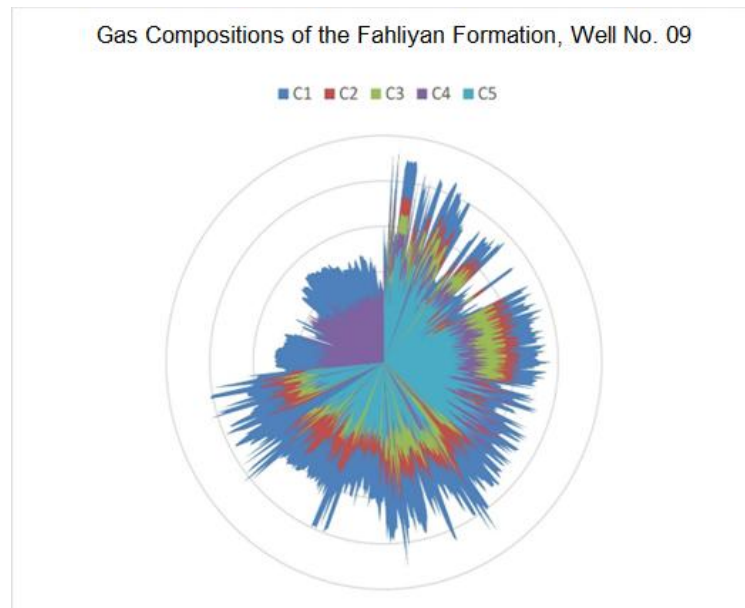


Figure 11: Gas Compositions of Well No. 09 – Fahliyan Formation

In the Fahliyan layer, the equilibrium index begins to rise, signifying an increase in the ratio of light to heavy gas components. Concurrently, the wettability values, which are linked to higher fluid density, are decreasing. Additionally, based on the Pixler ratios and the hydrocarbon index, there is strong evidence that the fluid is liquid, specifically oil. Using data from oil samples and comparing the hydrocarbon index values with Howard's (1984) classification tables, we conclude that the gas ratios correspond to light oil with high gravity. The oil gravity of the Fahliyan Formation is 38, which aligns well with our gas data.

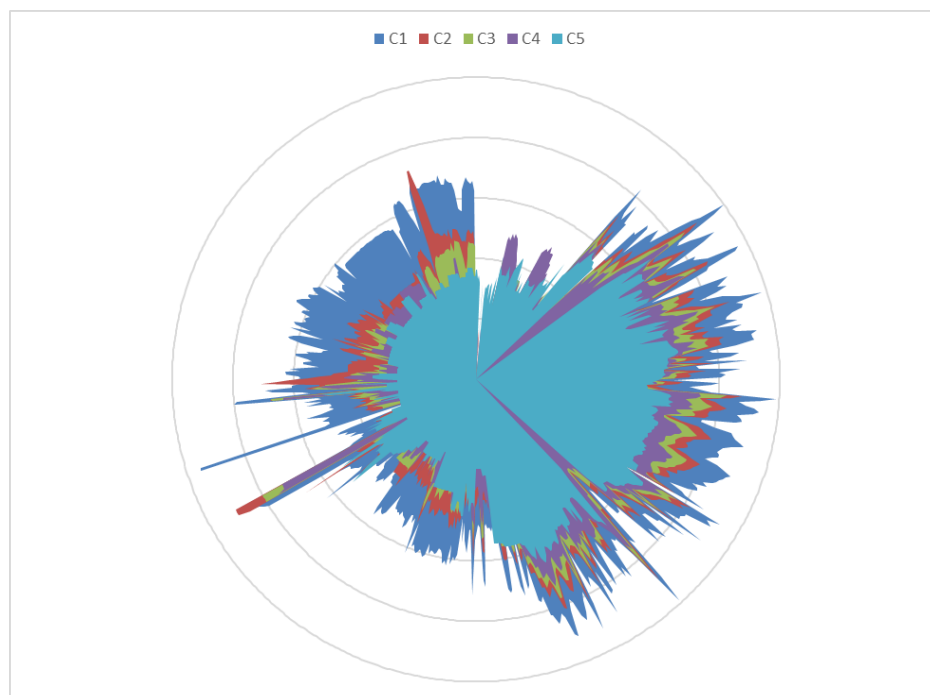


Figure 12: Gas Compositions of Well No. 19 – Fahliyan Formation

Table 3: Gas Compositions of Two Wells in the Yadavaran Field

BH>>WH BH>15 WH<20 Light oil	WH:5-10 BH:1-20 CH:1-5	C1/C2:2-10 C1/C3:2-15 C1/C4:2-4	Fahliyan	Well No. 09
BH>>WH BH>15 WH<20 Light oil	WH:2-15 BH:1- 20 CH:2-10	C1/C2:2-10 C1/C3:2-40 C1/C4:2-80	Fahliyan	Well No. 19

CONCLUSION

Based on the gas data from five wells in the Yadavaran field, along with the relationships between gas values, various Pixler diagrams, hydrocarbon balance, and wettability ratios for each well, the fluid type was determined for two wells. Furthermore, by analyzing the relationship between wettability ratios and hydrocarbon balance, we were able to classify the oil as either light or heavy. In the Fahliyan reservoir, oil with a standard gravity of 38 was identified, suggesting that the oil is sourced from two different source rocks. Variations in gas types provide insights into reservoir continuity. In this study, the differences in light and heavy gas values, as well as changes in lithology, indicated reservoir discontinuity. Overall, tracking gas values during drilling provides comprehensive information about the reservoir, which was thoroughly analyzed in this research.

To ensure accurate gas data, it is crucial to continuously monitor the gas exit paths from the drilling mud, especially the penetration rate of the gas trap device, which should always remain submerged in the mud. Fluctuations in the depth of the gas trap device within the mud can cause significant changes in the gas readings. By utilizing constant-volume gas trap devices, where the entry rate into the mud remains stable, we can effectively eliminate data fluctuations and ensure the accurate transmission of values for recording by the gas chromatograph.

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